FIG. 1

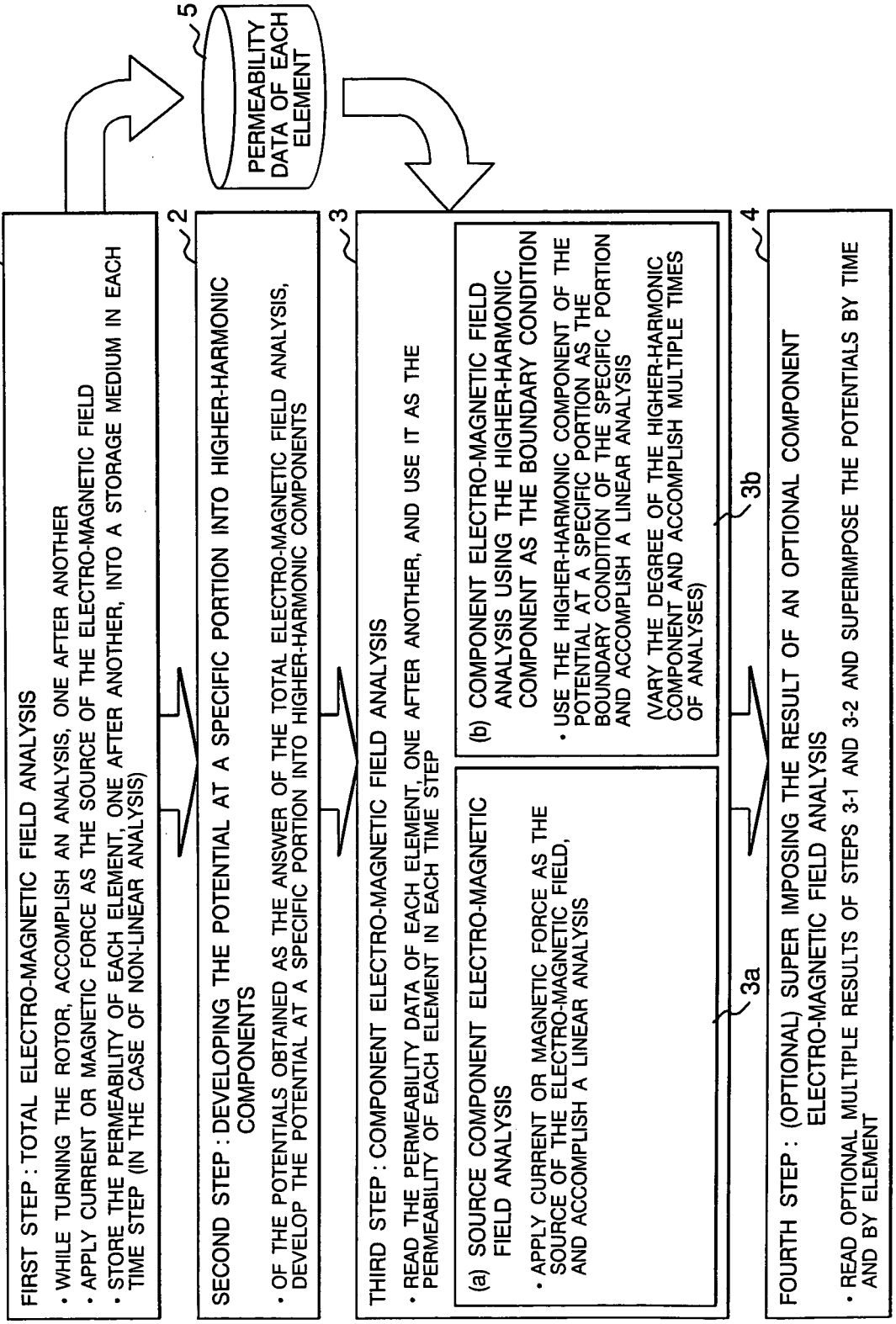
1
FIRST STEP : TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• WHILE TURNING THE ROTOR, ACCOMPLISH AN ANALYSIS, ONE AFTER ANOTHER
• APPLY CURRENT OR MAGNETIC FORCE AS THE SOURCE OF THE ELECTRO-MAGNETIC FIELD
• STORE THE PERMEABILITY OF EACH ELEMENT, ONE AFTER ANOTHER, INTO A STORAGE MEDIUM IN EACH TIME STEP (IN THE CASE OF NON-LINEAR ANALYSIS)
2
SECOND STEP : DEVELOPING THE POTENTIAL AT A SPECIFIC PORTION INTO HIGHER-HARMONIC COMPONENTS
• OF THE POTENTIALS OBTAINED AS THE ANSWER OF THE TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS, DEVELOP THE POTENTIAL AT A SPECIFIC PORTION INTO HIGHER-HARMONIC COMPONENTS
5
PERMEABILITY DATA OF EACH ELEMENT
3
THIRD STEP : COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• READ THE PERMEABILITY DATA OF EACH ELEMENT, ONE AFTER ANOTHER, AND USE IT AS THE PERMEABILITY OF EACH ELEMENT IN EACH TIME STEP
(a) SOURCE COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• APPLY CURRENT OR MAGNETIC FORCE AS THE SOURCE OF THE ELECTRO-MAGNETIC FIELD, AND ACCOMPLISH A LINEAR ANALYSIS
3a
(b) COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS USING THE HIGHER-HARMONIC COMPONENT AS THE BOUNDARY CONDITION
• USE THE HIGHER-HARMONIC COMPONENT OF THE POTENTIAL AT A SPECIFIC PORTION AS THE BOUNDARY CONDITION OF THE SPECIFIC PORTION AND ACCOMPLISH A LINEAR ANALYSIS
(VARY THE DEGREE OF THE HIGHER-HARMONIC COMPONENT AND ACCOMPLISH MULTIPLE TIMES OF ANALYSES)
3b
4
FOURTH STEP : (OPTIONAL) SUPER IMPOSING THE RESULT OF AN OPTIONAL COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• READ OPTIONAL MULTIPLE RESULTS OF STEPS 3-1 AND 3-2 AND SUPERIMPOSE THE POTENTIALS BY TIME AND BY ELEMENT

FIG. 2

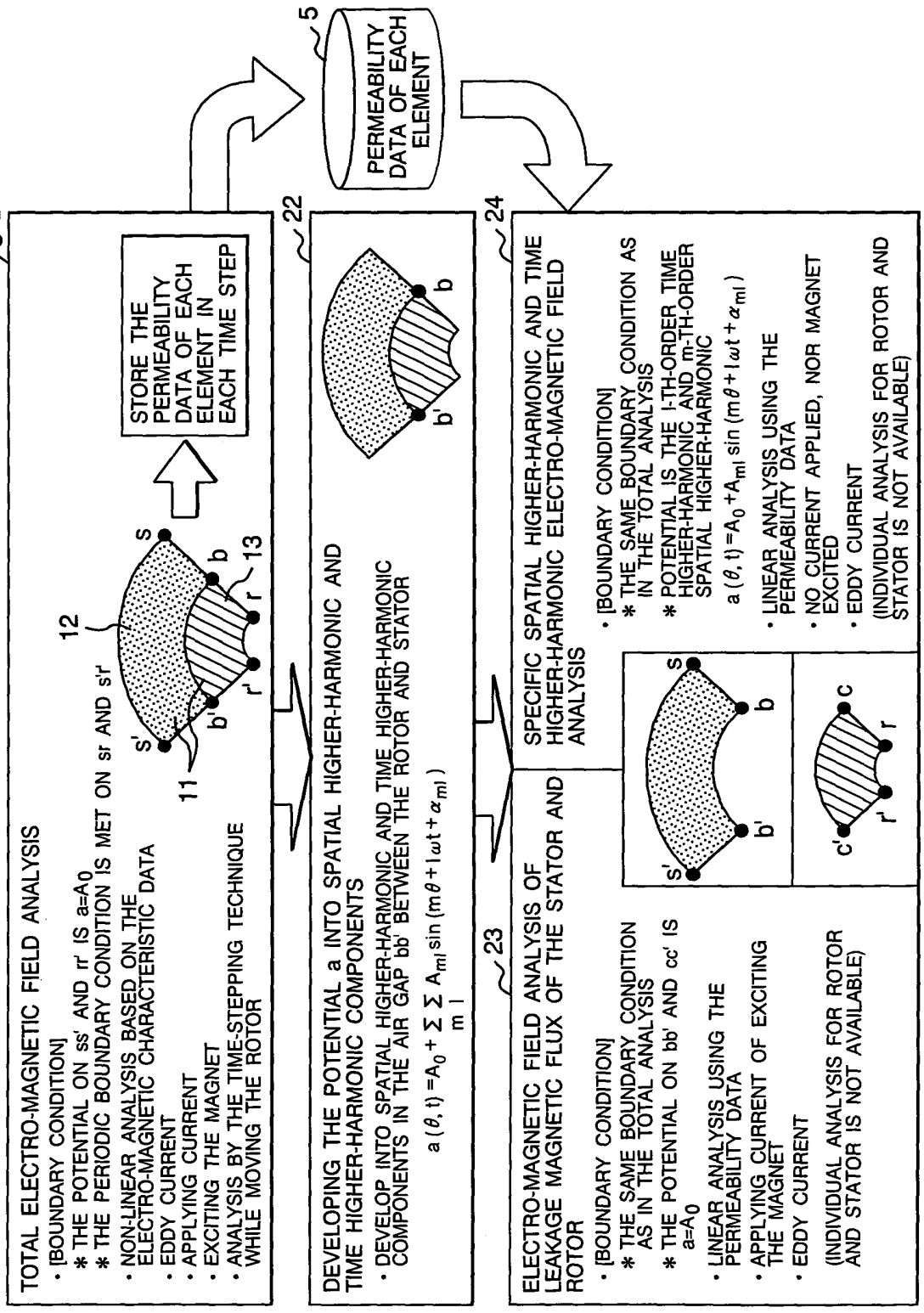
21
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON ss' AND rr' IS a=A0
* THE PERIODIC BOUNDARY CONDITION IS MET ON sr AND s'r'
• NON-LINEAR ANALYSIS BASED ON THE ELECTRO-MAGNETIC CHARACTERISTIC DATA
• EDDY CURRENT
• APPLYING CURRENT
• EXCITING THE MAGNET
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR
12
11
s
s'
b
b'
r
r'
13
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN EACH TIME STEP
5
PERMEABILITY DATA OF EACH ELEMENT
22
DEVELOPING THE POTENTIAL a INTO SPATIAL HIGHER-HARMONIC AND TIME HIGHER-HARMONIC COMPONENTS
• DEVELOP INTO SPATIAL HIGHER-HARMONIC AND TIME HIGHER-HARMONIC COMPONENTS IN THE AIR GAP bb' BETWEEN THE ROTOR AND STATOR
$a(\theta, t) = A_0 + \sum_m \sum_l A_{ml} \sin(m\theta + l\omega t + \alpha_{ml})$
b
b'
24
23
ELECTRO-MAGNETIC FIELD ANALYSIS OF LEAKAGE MAGNETIC FLUX OF THE STATOR AND ROTOR
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* THE POTENTIAL ON bb' AND cc' IS a=A0
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• APPLYING CURRENT OF EXCITING THE MAGNET
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
SPECIFIC SPATIAL HIGHER-HARMONIC AND TIME HIGHER-HARMONIC ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* POTENTIAL IS THE l-TH-ORDER TIME HIGHER-HARMONIC AND m-TH-ORDER SPATIAL HIGHER-HARMONIC
$a(\theta, t) = A_0 + A_{ml} \sin(m\theta + l\omega t + \alpha_{ml})$
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• NO CURRENT APPLIED, NOR MAGNET EXCITED
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
s
s'
b
b'
c
c'
r
r'

FIG. 3

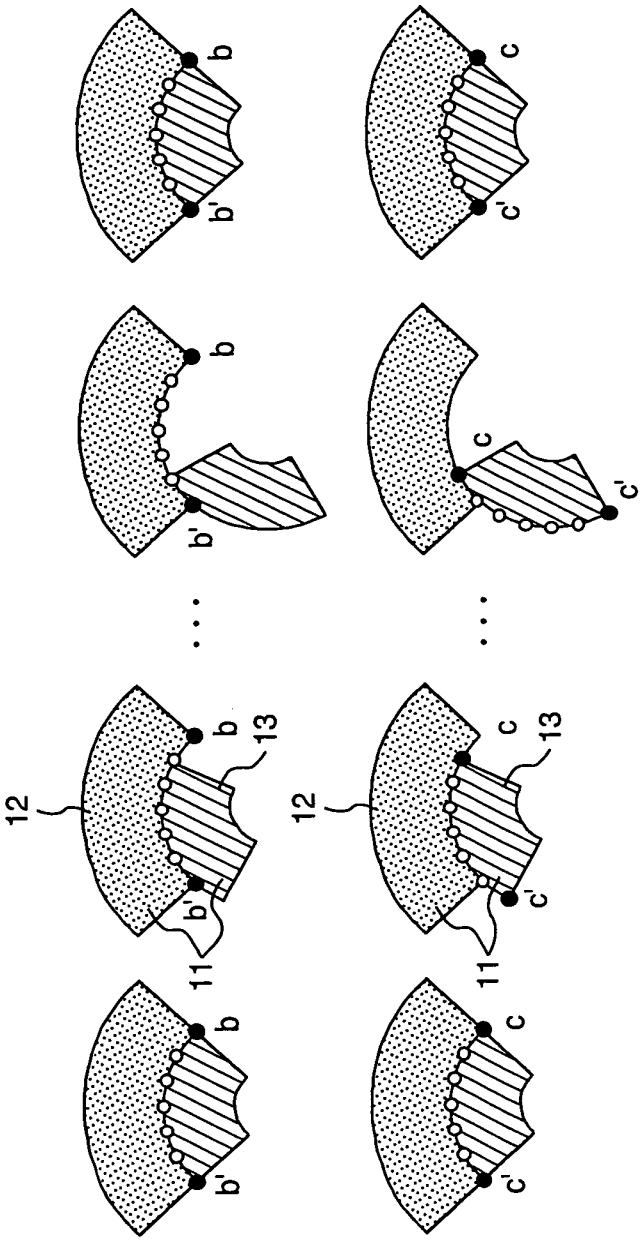

FIG. 4

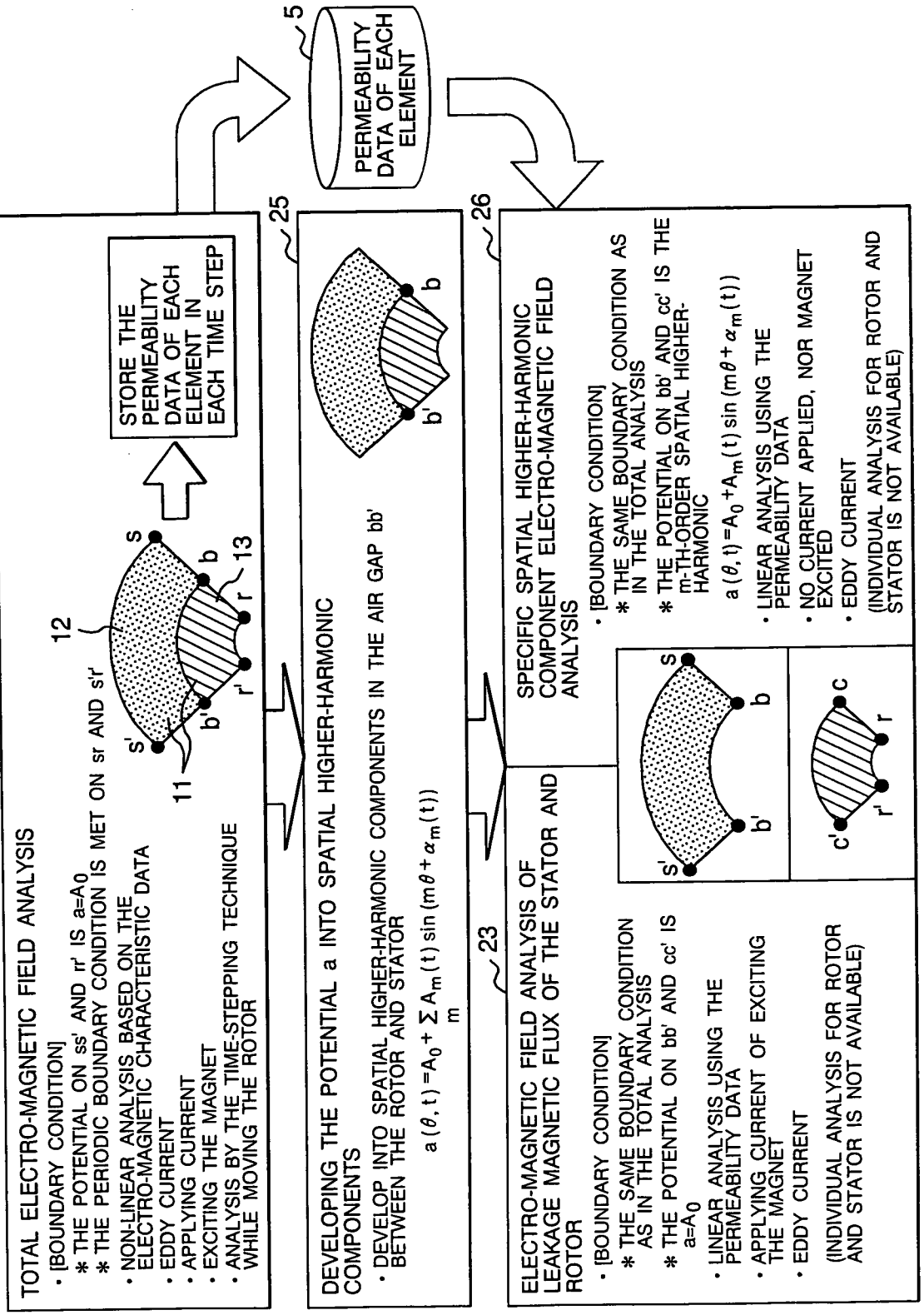
21
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON ss' AND rr' IS a=A0
* THE PERIODIC BOUNDARY CONDITION IS MET ON sr AND s'r'
• NON-LINEAR ANALYSIS BASED ON THE ELECTRO-MAGNETIC CHARACTERISTIC DATA
• EDDY CURRENT
• APPLYING CURRENT
• EXCITING THE MAGNET
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR
12
11
s
s'
b
b'
r
r'
13
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN EACH TIME STEP
5
PERMEABILITY DATA OF EACH ELEMENT
25
DEVELOPING THE POTENTIAL a INTO SPATIAL HIGHER-HARMONIC COMPONENTS
• DEVELOP INTO SPATIAL HIGHER-HARMONIC COMPONENTS IN THE AIR GAP bb' BETWEEN THE ROTOR AND STATOR
$a(\theta,t)=A_0+\sum_m A_m(t)\sin(m\theta+\alpha_m(t))$
b
b'
26
SPECIFIC SPATIAL HIGHER-HARMONIC COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* THE POTENTIAL ON bb' AND cc' IS THE m-TH-ORDER SPATIAL HIGHER-HARMONIC
$a(\theta,t)=A_0+A_m(t)\sin(m\theta+\alpha_m(t))$
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• NO CURRENT APPLIED, NOR MAGNET EXCITED
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
23
ELECTRO-MAGNETIC FIELD ANALYSIS OF LEAKAGE MAGNETIC FLUX OF THE STATOR AND ROTOR
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* THE POTENTIAL ON bb' AND cc' IS a=A0
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• APPLYING CURRENT OF EXCITING THE MAGNET
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
s'
s
b'
b
c'
c
r'
r

FIG. 5

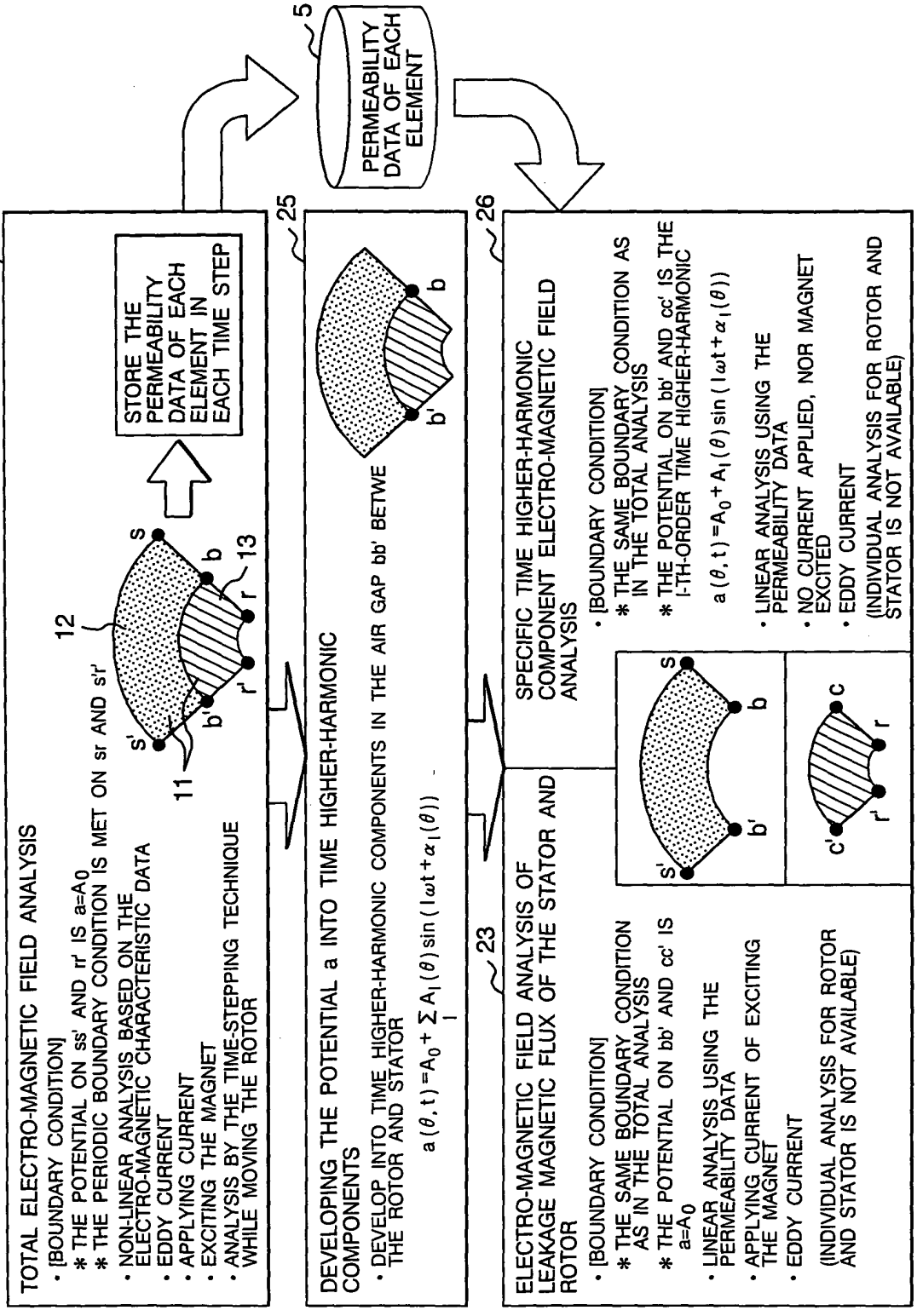
21
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON ss' AND rr' IS a=A0
* THE PERIODIC BOUNDARY CONDITION IS MET ON sr AND s'r'
• NON-LINEAR ANALYSIS BASED ON THE ELECTRO-MAGNETIC CHARACTERISTIC DATA
• EDDY CURRENT
• APPLYING CURRENT
• EXCITING THE MAGNET
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR
12
11
s'
s
b'
b
r'
r
13
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN EACH TIME STEP
5
PERMEABILITY DATA OF EACH ELEMENT
25
DEVELOPING THE POTENTIAL a INTO TIME HIGHER-HARMONIC COMPONENTS
• DEVELOP INTO TIME HIGHER-HARMONIC COMPONENTS IN THE AIR GAP bb' BETWE THE ROTOR AND STATOR
$a(\theta,t)=A_0+\sum_l A_l(\theta)\sin(l\omega t+\alpha_l(\theta))$
b
b'
26
23
ELECTRO-MAGNETIC FIELD ANALYSIS OF LEAKAGE MAGNETIC FLUX OF THE STATOR AND ROTOR
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* THE POTENTIAL ON bb' AND cc' IS a=A0
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• APPLYING CURRENT OF EXCITING THE MAGNET
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
SPECIFIC TIME HIGHER-HARMONIC COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS
* THE POTENTIAL ON bb' AND cc' IS THE l-TH-ORDER TIME HIGHER-HARMONIC
$a(\theta,t)=A_0+A_l(\theta)\sin(l\omega t+\alpha_l(\theta))$
• LINEAR ANALYSIS USING THE PERMEABILITY DATA
• NO CURRENT APPLIED, NOR MAGNET EXCITED
• EDDY CURRENT
(INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS NOT AVAILABLE)
s'
s
b'
b
c'
c
r'
r

FIG. 6

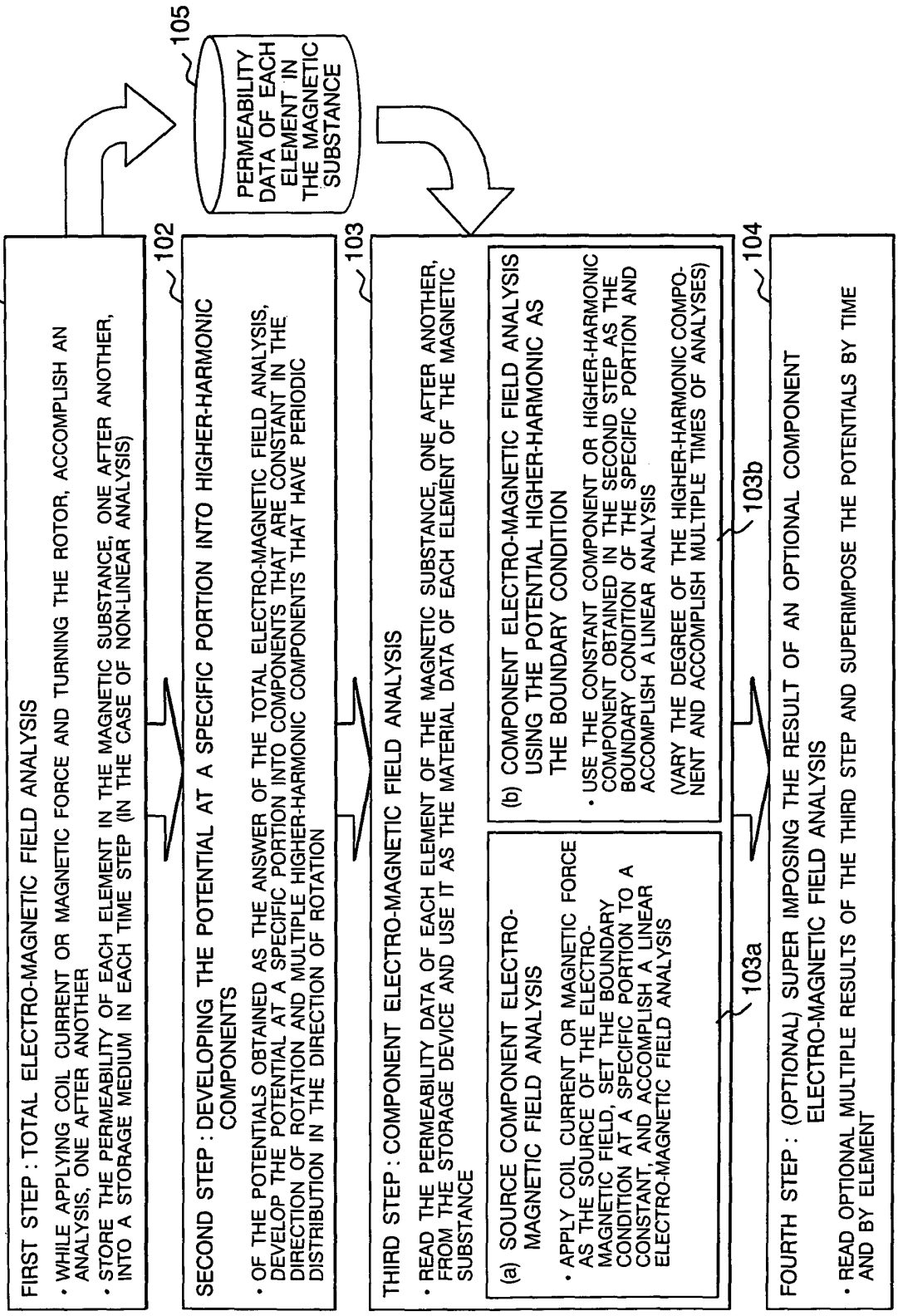
101
FIRST STEP : TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• WHILE APPLYING COIL CURRENT OR MAGNETIC FORCE AND TURNING THE ROTOR, ACCOMPLISH AN ANALYSIS, ONE AFTER ANOTHER
• STORE THE PERMEABILITY OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE, ONE AFTER ANOTHER, INTO A STORAGE MEDIUM IN EACH TIME STEP (IN THE CASE OF NON-LINEAR ANALYSIS)
102
SECOND STEP : DEVELOPING THE POTENTIAL AT A SPECIFIC PORTION INTO HIGHER-HARMONIC COMPONENTS
• OF THE POTENTIALS OBTAINED AS THE ANSWER OF THE TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS, DEVELOP THE POTENTIAL AT A SPECIFIC PORTION INTO COMPONENTS THAT ARE CONSTANT IN THE DIRECTION OF ROTATION AND MULTIPLE HIGHER-HARMONIC COMPONENTS THAT HAVE PERIODIC DISTRIBUTION IN THE DIRECTION OF ROTATION
103
THIRD STEP : COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• READ THE PERMEABILITY DATA OF EACH ELEMENT OF THE MAGNETIC SUBSTANCE, ONE AFTER ANOTHER, FROM THE STORAGE DEVICE AND USE IT AS THE MATERIAL DATA OF EACH ELEMENT OF THE MAGNETIC SUBSTANCE
(a) SOURCE COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• APPLY COIL CURRENT OR MAGNETIC FORCE AS THE SOURCE OF THE ELECTRO-MAGNETIC FIELD, SET THE BOUNDARY CONDITION AT A SPECIFIC PORTION TO A CONSTANT, AND ACCOMPLISH A LINEAR ELECTRO-MAGNETIC FIELD ANALYSIS
103a
(b) COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS USING THE POTENTIAL HIGHER-HARMONIC AS THE BOUNDARY CONDITION
• USE THE CONSTANT COMPONENT OR HIGHER-HARMONIC COMPONENT OBTAINED IN THE SECOND STEP AS THE BOUNDARY CONDITION OF THE SPECIFIC PORTION AND ACCOMPLISH A LINEAR ANALYSIS
(VARY THE DEGREE OF THE HIGHER-HARMONIC COMPONENT AND ACCOMPLISH MULTIPLE TIMES OF ANALYSES)
103b
104
FOURTH STEP : (OPTIONAL) SUPER IMPOSING THE RESULT OF AN OPTIONAL COMPONENT ELECTRO-MAGNETIC FIELD ANALYSIS
• READ OPTIONAL MULTIPLE RESULTS OF THE THIRD STEP AND SUPERIMPOSE THE POTENTIALS BY TIME AND BY ELEMENT
105
PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE

FIG. 7

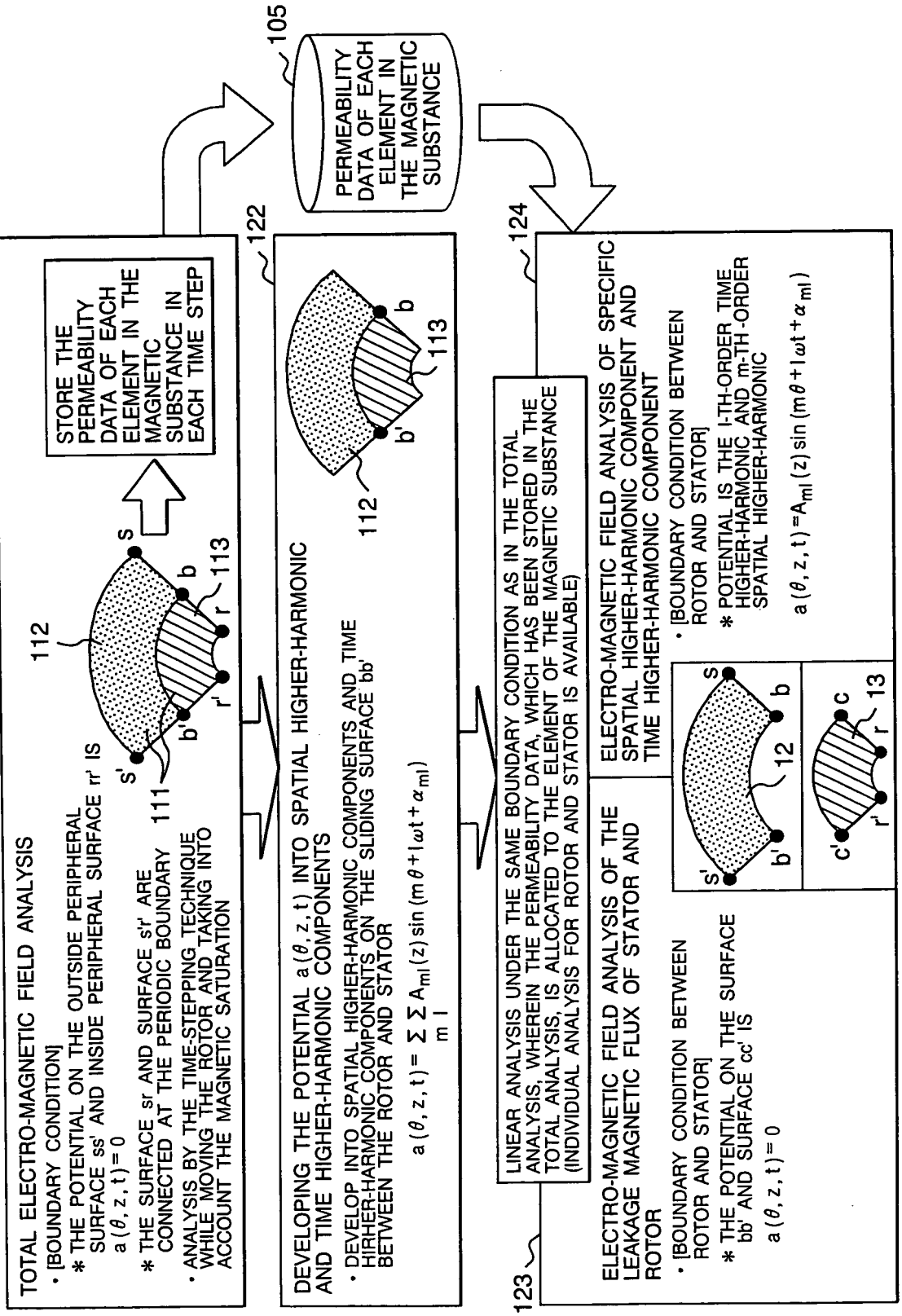
121
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON THE OUTSIDE PERIPHERAL SURFACE rr' IS a(θ, z, t) = 0
* THE SURFACE sr AND SURFACE s'r' ARE CONNECTED AT THE PERIODIC BOUNDARY
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR AND TAKING INTO ACCOUNT THE MAGNETIC SATURATION
112
111
s
s'
b
b'
r
r'
113
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE IN EACH TIME STEP
105
PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE
122
DEVELOPING THE POTENTIAL a(θ, z, t) INTO SPATIAL HIGHER-HARMONIC AND TIME HIGHER-HARMONIC COMPONENTS
• DEVELOP INTO SPATIAL HIGHER-HARMONIC COMPONENTS AND TIME HIGHER-HARMONIC COMPONENTS ON THE SLIDING SURFACE bb' BETWEEN THE ROTOR AND STATOR
$a(\theta, z, t) = \sum_m \sum_l A_{ml}(z) \sin(m\theta + l\omega t + \alpha_{ml})$
112
113
b
b'
124
LINEAR ANALYSIS UNDER THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS, WHEREIN THE PERMEABILITY DATA, WHICH HAS BEEN STORED IN THE TOTAL ANALYSIS, IS ALLOCATED TO THE ELEMENT OF THE MAGNETIC SUBSTANCE (INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS AVAILABLE)
123
ELECTRO-MAGNETIC FIELD ANALYSIS OF THE LEAKAGE MAGNETIC FLUX OF STATOR AND ROTOR
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* THE POTENTIAL ON THE SURFACE bb' AND SURFACE cc' IS
a(θ, z, t) = 0
ELECTRO-MAGNETIC FIELD ANALYSIS OF SPECIFIC SPATIAL HIGHER-HARMONIC COMPONENT AND TIME HIGHER-HARMONIC COMPONENT
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* POTENTIAL IS THE l-TH-ORDER TIME HIGHER-HARMONIC AND m-TH-ORDER SPATIAL HIGHER-HARMONIC
$a(\theta, z, t) = A_{ml}(z) \sin(m\theta + l\omega t + \alpha_{ml})$
s
s'
b
b'
12
c
c'
r
r'
13

FIG. 8

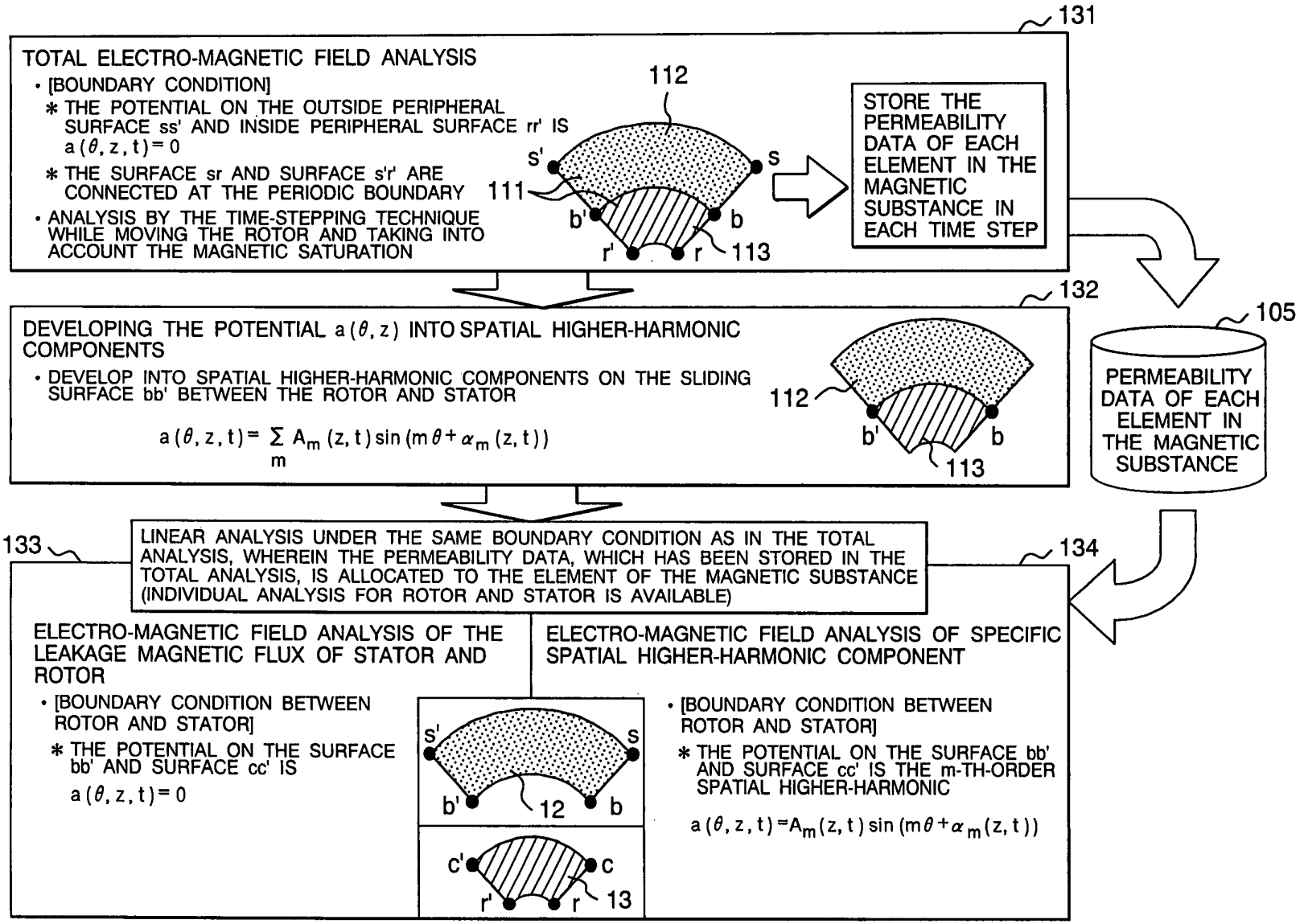
131
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON THE OUTSIDE PERIPHERAL SURFACE ss' AND INSIDE PERIPHERAL SURFACE rr' IS a(θ, z, t) = 0
* THE SURFACE sr AND SURFACE s'r' ARE CONNECTED AT THE PERIODIC BOUNDARY
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR AND TAKING INTO ACCOUNT THE MAGNETIC SATURATION
112
s'
s
111
b'
b
r'
r
113
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE IN EACH TIME STEP
132
DEVELOPING THE POTENTIAL a(θ, z) INTO SPATIAL HIGHER-HARMONIC COMPONENTS
• DEVELOP INTO SPATIAL HIGHER-HARMONIC COMPONENTS ON THE SLIDING SURFACE bb' BETWEEN THE ROTOR AND STATOR
$a(\theta, z, t) = \sum_m A_m(z, t) \sin(m\theta + \alpha_m(z, t))$
112
b'
b
113
105
PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE
133
LINEAR ANALYSIS UNDER THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS, WHEREIN THE PERMEABILITY DATA, WHICH HAS BEEN STORED IN THE TOTAL ANALYSIS, IS ALLOCATED TO THE ELEMENT OF THE MAGNETIC SUBSTANCE (INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS AVAILABLE)
134
ELECTRO-MAGNETIC FIELD ANALYSIS OF THE LEAKAGE MAGNETIC FLUX OF STATOR AND ROTOR
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* THE POTENTIAL ON THE SURFACE bb' AND SURFACE cc' IS a(θ, z, t) = 0
s'
s
b'
12
b
c'
c
r'
r
13
ELECTRO-MAGNETIC FIELD ANALYSIS OF SPECIFIC SPATIAL HIGHER-HARMONIC COMPONENT
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* THE POTENTIAL ON THE SURFACE bb' AND SURFACE cc' IS THE m-TH-ORDER SPATIAL HIGHER-HARMONIC
$a(\theta, z, t) = A_m(z, t) \sin(m\theta + \alpha_m(z, t))$

FIG. 9

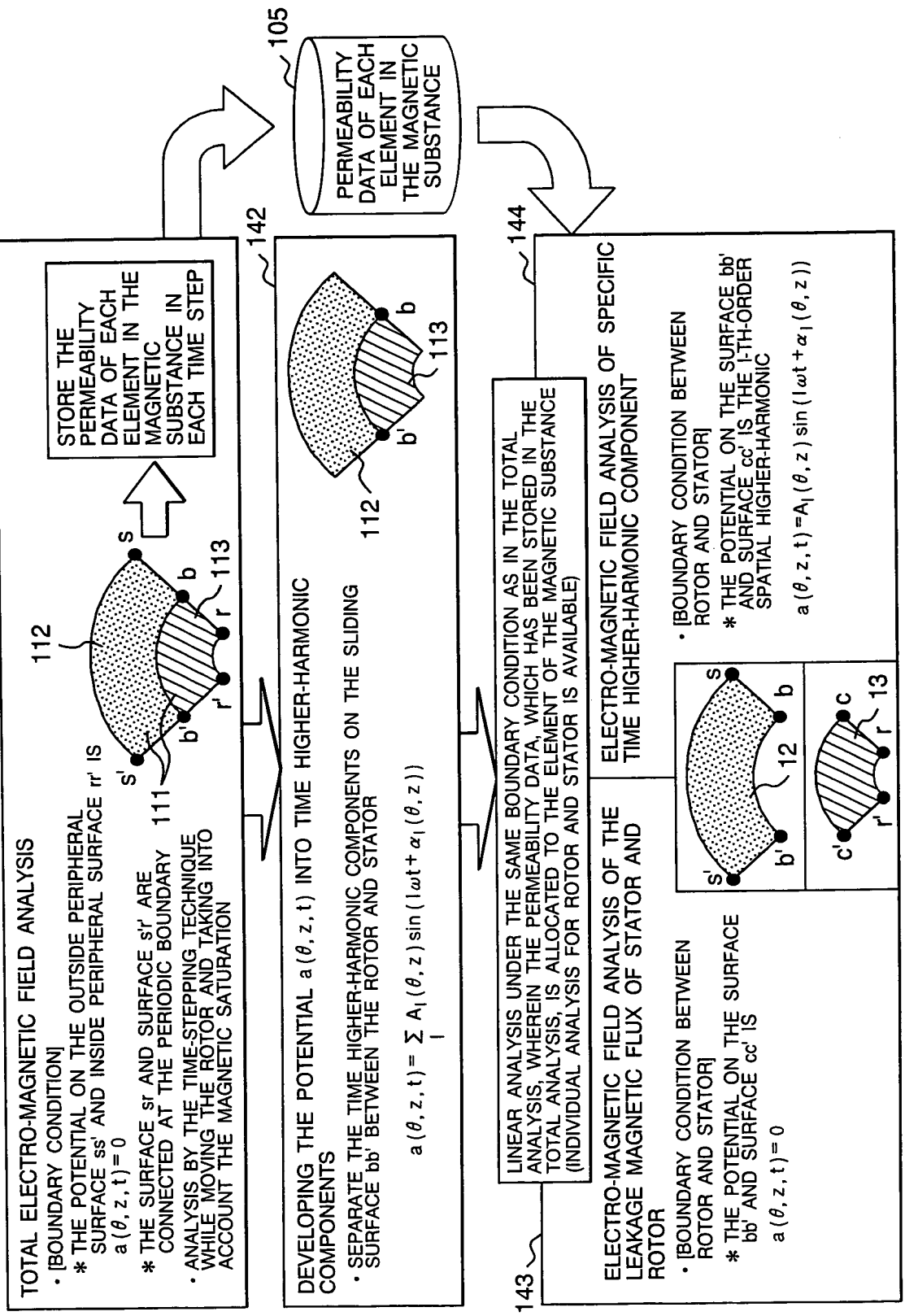
141
TOTAL ELECTRO-MAGNETIC FIELD ANALYSIS
• [BOUNDARY CONDITION]
* THE POTENTIAL ON THE OUTSIDE PERIPHERAL SURFACE rr' IS a(θ, z, t) = 0
* THE SURFACE sr AND SURFACE s'r' ARE CONNECTED AT THE PERIODIC BOUNDARY
• ANALYSIS BY THE TIME-STEPPING TECHNIQUE WHILE MOVING THE ROTOR AND TAKING INTO ACCOUNT THE MAGNETIC SATURATION
112
111
s
s'
b
b'
r
r'
113
STORE THE PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE IN EACH TIME STEP
105
PERMEABILITY DATA OF EACH ELEMENT IN THE MAGNETIC SUBSTANCE
142
DEVELOPING THE POTENTIAL a(θ, z, t) INTO TIME HIGHER-HARMONIC COMPONENTS
• SEPARATE THE TIME HIGHER-HARMONIC COMPONENTS ON THE SLIDING SURFACE bb' BETWEEN THE ROTOR AND STATOR
$a(\theta, z, t) = \sum_{l} A_l(\theta, z) \sin(l\omega t + \alpha_l(\theta, z))$
112
113
b
b'
144
LINEAR ANALYSIS UNDER THE SAME BOUNDARY CONDITION AS IN THE TOTAL ANALYSIS, WHEREIN THE PERMEABILITY DATA, WHICH HAS BEEN STORED IN THE TOTAL ANALYSIS, IS ALLOCATED TO THE ELEMENT OF THE MAGNETIC SUBSTANCE (INDIVIDUAL ANALYSIS FOR ROTOR AND STATOR IS AVAILABLE)
143
ELECTRO-MAGNETIC FIELD ANALYSIS OF THE LEAKAGE MAGNETIC FLUX OF STATOR AND ROTOR
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* THE POTENTIAL ON THE SURFACE bb' AND SURFACE cc' IS a(θ, z, t) = 0
ELECTRO-MAGNETIC FIELD ANALYSIS OF SPECIFIC TIME HIGHER-HARMONIC COMPONENT
• [BOUNDARY CONDITION BETWEEN ROTOR AND STATOR]
* THE POTENTIAL ON THE SURFACE bb' AND SURFACE cc' IS THE l-TH-ORDER SPATIAL HIGHER-HARMONIC
$a(\theta, z, t) = A_l(\theta, z) \sin(l\omega t + \alpha_l(\theta, z))$
s
s'
b
b'
12
c
c'
r
r'
13

FIG. 10